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(71) Applicant: FRAMO DEVELOPMENTS (U.K.) LIMITED
108 Coombe Lane
London SW20 OAY (GB)
Applicant: NORSK HYDRO A.S.
Bygdøyallé 2
N-Oslo 2 (NO)

(72) Inventor: Mohn, Frank
108 Coombe Lane
London SW20 OAY (GB)
Inventor: Martin, Wallace William
Nordahl Griegsvei 18
N-5043 HOP (NO)

(74) Representative: Hector, Annabel Mary
W.P. Thompson & Co.
Celcon House
289-293 High Holborn
GB-London WC1V 7HU (GB)

(54) **Mixing or homogenizing a first liquid and a second liquid or a gas.**

(57) A liquid is supplied to a vessel (10) to form a pool (21) from which it discharges through a venturi. A supply pipe or pipes (12,30) convey other liquids and/or gases from separate sources or from above the liquid pool into the venturi for mixing with the liquid. The supply pipes can extend through the pool and be perforated (22) to tend to maintain the level of the pool. Associated with the venturi are pressure sensors (40,41) for measuring flow and a densiometer (52) permitting mass flow rate measurement of gas and liquid phases. The apparatus can be incorporated in a cartridge (60) for reception in a receptacle (61) at a subsea installation.

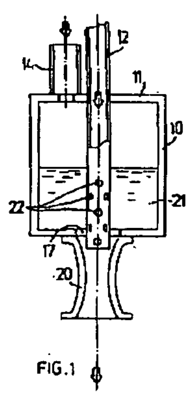

FIG.1

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(3.10/3.09/3.3.4)

The invention relates to an apparatus for and a method of mixing or homogenizing a first liquid and a second liquid or gas.

There is known from US-A-3 556 141 a device comprising a conduit provided with a venturi through which flows a stream of water. Liquid fertilizer is jected into the water stream just downstream of the venturi, through a metering valve from a container, by the pressure drop due to the venturi.

The invention provides an apparatus for mixing together or homogenizing a liquid and a gas, the apparatus comprising a vessel for receiving therein a pool of the liquid and a body of the gas above the pool, an opening in the vessel communicating with a discharge duct, tubing communicating the interior of the vessel with the discharge duct, a constriction in the discharge duct functioning as a venturi for mixing together the liquid from the pool and the gas from the body discharging through the duct, and flowmetering means for measuring flow through the venturi.

The invention also provides a method of measuring flow of a mixed or homogenized liquid and gas, the method comprising forming a pool of the liquid in a vessel and a body of the gas in the vessel above the liquid pool, discharging the gas from the body and the liquid from the liquid pool into a discharge duct constricted to include a venturi, and measuring the flow of the mixed or homogenized liquid and gas through the venturi by sensing pressure change thereat.

The flow into the discharge duct can be induced by gravity, the outlet from the chamber being then located in its floor. An apparatus in accordance with the invention can nevertheless be designed to be located directly upstream of a suitable pump or booster.

Preferably, the apparatus incorporates means tending to maintain a level of the liquid in the vessel or chamber. The invention can accordingly provide that the or each conduit conveying a liquid or a gas into the venturi, otherwise than through the opening, extends through the pool of the liquid in the chamber and is provided with apertures or perforations. The amount of the liquid drawn off from the liquid pool thus increases as a function of the increase of the liquid level, as more of the perforations are submerged.

The invention can be applied to the homogenization and/or measurement of a mixture of oil, water and gas, and can be embodied in a form suitable for subsea use. The invention thus also provides a flowmeter cartridge, which can incorporate a choke, arranged for subsea installation, as by installation in a barrel receptacle connected to a X'mas tree.

The invention can thus provide a multiphase process mixing and measuring system, or a system by which two or more fluid materials, that is, liquids, gases or vapours, are mixed and by which the mixed materials can be metered if desired.

It will be evident that the invention has a variety of applications particularly in the oil industry, where it can be applied to chemical injection and blending as well as to on-shore and off-shore handling of crude oil. In its aspect as a homogenizing apparatus, it is applicable in particular to the mixing or homogenization of mixtures of gas and oil extracted from on-shore or subsea wells. The fluid extracted from such wells can vary substantially as regards its gas and liquid components. It may comprise slugs of substantially unmixed liquid separate by primarily gaseous portions, as well as portions that are more or less homogeneous. This inconsistency of the nature of the extracted material makes it difficult to handle, in particular by pumping equipment.

The invention is further described below, by way of example, with reference to the accompanying drawings, in which:

Figures 1 and 3 are sectional side views of mixing or homogenizing apparatus in accordance with the invention;

Figure 2 in a sectional side view of a mixing or homogenising apparatus in accordance with an invention claimed in our copending application no. 90907359.5, from which this application is divided;

Figure 4 is a part-sectional side view of a receptacle of a subsea installation having received therein a cartridge incorporating an apparatus as illustrated in Figure 2;

Figure 5 is a side view of the subsea installation in which the receptacle is mounted; and

Figure 6 is a plan view on a smaller scale of the subsea installation.

The mixer apparatus of Figure 1 comprises an upright cylindrical container 10, the upper end wall 11, of which is provided with a central aperture through which a pipe 12 extends along the container axis. Adjacent the pipe 12, an upright inlet duct 14 communicates with the container interior through a second aperture in the upper end wall 11 offset from the axis. The lower end wall 16 of the container has a central outlet 17 by which the container communicates with a hollow discharge fitting 20 of which the interior is shaped to function as a venturi. Th central pipe 12 extends, with spacing, through the outlet 17, with its open lower end just within the fitting 20.

A liquid introduced into the container through the inlet duct 14 at an appropriate flow rate forms a pool 21 from which the liquid flows under gravity through the outlet 17 and the discharge fitting 20. A second

liquid or a gas available by way of the pipe 12 will be drawn by the venturi along the pipe and so effectively mixed with the liquid entering through the duct 14. The pipe 12 is provided with apertures or perforations 22 over at least its lower region so that th liquid in the pool 21 can enter the venturi by way of the pip as well as through the outlet 17. A degree of regulation of the level of the pool 21 is thus obtained, in that more of the perforations 22 become available for the liquid to discharge as the level of the pool rises.

The apparatus of Figure 1 is thus intended for mixing together a liquid from a first external source with another liquid or a gas from a second, different, external source. The apparatus has a variety of applications as for chemical injection or the drip feed of additives to a liquid.

The form of apparatus shown in Figure 2 is arranged for mixing together liquid and gaseous phases occurring in a single incoming fluid supply, and thus functions as a homogenizer. In the following description of the apparatus of Figures 2 and 3, reference numerals already used in Figure 1 are used again for like or similar parts.

The apparatus of Figure 2 differs from that of Figure 1 in that the fluid source for the central pipe 12 is the upper part of the container interior. For this purpose, the central pipe 12 does not extend upwardly beyond the upper end wall 11, which is provided with a second axially offset aperture 25. A sub-container 26, in the form of a cylinder of lesser axial length and diameter than the main container, and through which the inlet duct 14 extends, is mounted on the upper end wall 11 and both the aperture 25 and the pipe 12 communicate with it.

The liquid phase of a multi-phase fluid flow entering the container 10 by way of the inlet duct 14 tends to separate under gravity from the gaseous phase and forms the pool 21 in the lower part of the container. The gaseous phase occupies the upper part of the container, above the surface of the liquid pool. The liquid phase is withdrawn from the pool 21 through the discharge fitting 20 under gravity and the effect of the venturi is to draw gas from the upper part of the container through the aperture 25, the sub-container 26 and the central pipe 12 into the venturi. The liquid phase is consequently mixed with the liquid phase, so that a homogenized or substantially homogenized fluid is obtained in the discharge fitting 20. If the multi-phase fluid flow entering the container is already homogenous or approximately so, then the mixture will be discharged through the discharge fitting by way of both the opening 17 and the pipe 12.

The void fraction α of the fluid discharged from the container 10 depends on the dimensions of the venturi, and can be made independent of the total flow rate Q^T, the liquid level h in the container, and the absolute pressure ρ.

Assuming that both some liquid and some gas are present in the container 10, the total pressure drop for the gas and for the liquid phases flowing through it will be equal, and the void fraction from the container can be obtained from the resulting equation as follows:

$$\frac{\rho_L}{2}(1-\alpha)^2 \cdot Q_T^2 \left[\frac{(1+\xi_L)}{A_L^2} - \frac{1}{A_T^2} - \frac{2 \cdot g \cdot h}{(1-\alpha)^2 \cdot Q_T^2}\right] = \frac{\rho_G}{2}\alpha^2 \cdot Q_T^2 \left[\frac{(1+\xi_G)}{A_G^2} - \frac{1}{A_T^2}\right]$$

where:

- A_T - the cross-sectional area of the container,
- A_L - the cross-sectional area of the liquid in the venturi,
- A_G - the cross-sectional area of the gas in the venturi,
- ξ_L - the total liquid loss coefficient,
- ξ_G - the total gas loss coefficient,
- ρ_L - the liquid density,
- ρ_G - the gas density, and
- g - gravity.

During steady flow conditions, the average void fraction drawn from the container will equal the average void fraction entering it. To ensure that both liquid and gas are always present in the container, it is convenient to decrease the gas fraction drawn off as the liquid level increases, and vice versa, and this is achieved by the perforations 22 in the central pipe 12. The perforated pipe portion 22 thus acts as an integral regulator allowing a variation in the void fraction. Any desired mixing unit characteristic can be obtained by appropriate choice of dimensions of the venturi and the perforations 25 in the pipe portion 22.

In some applications of the apparatus of Figure 2, it may be desired to introduce a fluid additive into the homogenized flow discharged from the fitting 210 and this can be readily achieved by means of the form of apparatus shown in Figure 3.

The apparatus of Figure 3 resembles that of Figure 2 but with the addition of a tube 30 received coaxially with spacing, within th tube 12. The inner tube 30 extends to the lower end of the tube 12 and communicates at its upper end with a source of the desired liquid or gaseous additive, which is drawn into the venturi fitting together with the liquid phas from the pool 21 and the gaseous phase above it, so as to be effectively mixed together with these phases. An inner tube such as the tube 30 could be added to the apparatus of the other Figures where it is desired to mix more than one fluid with the liquid supplied through the inlet duct 14.

In some applications of the forms of apparatus illustrated in Figures 1, 2 and 3, it is desirable to provide a measure of the fluid flow passing through the apparatus and the apparatus can be connected to a downstream flowmeter. However, as each form of the apparatus includes a venturi, flow measuring means of the kind dependent on the pressure drop occurring in a venturi can readily be integrated with the mixer apparatus.

Thus as schematically shown in Figure 2 only, although applicable also to the apparatus of Figure 1 and Figure 3, the fitting 20 mounts axially spaced upstream and downstream pressure probes or gauges 40 and 41 which provide output signals, which represent sensed fluid pressure. The upstream gauge 40 is located at the entry to the Venturi throat and the gauge 41 is located at the throat itself. The gauge output signals are supplied to a processing equipment 50. Spaced upstream and downstream temperature sensors 45 and 46 are also carried by the fitting 20, at respective axial locations corresponding to those of the pressure gauges 40 and 41. Output signals representing sensed temperature are supplied from the sensors 45 and 46 to the processing equipment 50. The output signals from the temperature sensors 45 and 46 are employed in the processing equipment 50, which provides outputs to a display and/or a recording device 51, to compensate for variations in density due to temperature changes.

The mixture flowing through the fitting 20 comprises both gaseous and liquid phases and the mass flow rates of the separate phases can be computed by the processing equipment 50 by the supply to it of output signals from a densiometer 54 which can be of any suitable kind for example a y-ray or x-ray densiometer. The homogenized nature of the fluid flow in the fitting 20 ensures an accurate result.

Although reference has been made to fluid flow through the apparatus of Figures 1, 2 and 3 under gravity, the flow can be boosted or induced by a downstream booster 31 or pump, schematically indicated Figure 3 only, but applicable also to the apparatus of Figure 1 or Figure 2, mounted below the discharge or venturi fitting 20.

The present invention has application particularly but not exclusively in the oil industry. For example, crude oil comprising a mixture of gas, oil and water can be fed through the apparatus of Figure 2. For use in subsea installation, the apparatus can be incorporated as shown in Figure 4 into a cartridge 60 for reception in an upright open-topped receptacle 61 located at the installation. The receptacle 61 can be mounted as shown in Figures 5 and 6 on a frame for a satellite production X'mas tree 63, conveniently on the opposite side of the X'mas tree from a control module 62, to assist in balancing the frame.

The cartridge 60 has upper, intermediate and lower sealing means 64,65 & 66 of equal diameter for sealing to a lower portion of the receptacle 61, of uniform inner cross-section. The sealing means are activated by hydraulic pressure after entry of the cartridge 61 into the receptacle. The space between the upper and intermediate sealing means 64 and 65 defines a sealed entrance chamber into which the crude oil which is carried by piping 69 through an aperture in the receptacle wall. From the entrance chamber, the crude oil enters the container 10 of the mixing or homogenizing apparatus through which it flows. The lower sealing means 66 defines the lower end of a discharge chamber into which the mixed and measured crude oil flow enters from the lower end of the fitting 20 of the apparatus, and from which it is discharged outwardly of the receptacle through an aperture in the receptacle wall into piping 70.

Electrical and hydraulic power connection to the cartridge 60 is effected through coupling arrangements comprising an aperture formed in the base wall of the receptacle 61 and a connector plug 72 protruding from the lower end of the cartridge and which is introduced into the aperture by a stab-in operation during installation of the cartridge. Above the upper sealing means 64, the cartridge 60 comprises a connector 74, by which it is mechanically locked down within an upper portion of the receptacle of greater diameter than the lower portion, and a running neck 75 by which it is lowered into the receptacle during installation and can be lifted if retrieval is necessary, by means of a dedicated running tool.

Electrical and hydraulic connections with the cartridge 61 are made by way of the connector plug 72 and an electric/hydraulic signal integrator 76 located below the lowest sealing means 66. The cartridge can if desired incorporate a choke 80 which may be located upstream of the flowmeter apparatus as shown or downstream of it, and to which connections extend from the integrator 76, as well as to the flowmeter apparatus, unless the choke comprises a mechanically operated choke valve. Control and information signals are routed through the plug 72 and the integrator 76 between the cartridg and the X'mas tree

control module 62 and through an umbilical 81 for the installation to a control centre.

Th flowmeter cartridge 60 and the receptacle 61 are mounted downstream of the X'mas tree 63 wing valve to which it is connected by means of a hard piped flange connection, so that the crude oil flows continuously from the tree through a master valve and the wing valve to the cartridge and outwardly to transport piping by way of a flowbase connector.

Claims

1. An apparatus for mixing together or homogenizing a liquid and a gas, the apparatus comprising a vessel (10) for receiving therein a pool (21) of the liquid and a body of the gas above the pool, an opening (17) in the vessel communicating with a discharge duct (20), tubing (12) communicating the interior of the vessel with the discharge duct, a constriction in the discharge duct functioning as a venturi for mixing together the liquid from the pool and the gas from the body discharging through the duct, and flowmetering means for measuring flow through the venturi.

2. An apparatus as claimed in claim 1 wherein the tubing (12) communicates with both the liquid and the gas.

3. An apparatus as claimed in claim 2 wherein the tubing (12) communicates with the liquid by means of apertures spaced along its length so that the amount of liquid entering the tubing depends on the level of the pool (21).

4. An apparatus as claimed in claim 1, 2 or 3 wherein the vessel has a common inlet (14) for the liquid and the gas.

5. An apparatus as claimed in any one of the preceding claims wherein the flowmetering means comprises pressure sensors (40,41) located respectively at the entry to the venturi throat and at the throat, processing means (50) for processing the sensor outputs, and display and/or recording means (51) responsive to the processing means output.

6. An apparatus as claimed in claim 5 wherein the flowmetering means comprises sensors (45,46) responsive to fluid temperature at the pressure sensors (40,41) and wherein the processing means (50) employs the temperature sensor outputs to compensate for temperature dependent density changes.

7. An apparatus as claimed in claim 5 or 6 wherein the flowmetering means includes a densiometer (54) and the processing means (50) is responsive to the outputs of the pressure sensors and the densiometer to compute the mass flow rates of gaseous and liquid phases in the venturi duct.

8. An apparatus as claimed in any preceding claim wherein the discharge duct opening (17) is in the lower region of the vessel (10).

9. An apparatus as claimed in any preceding claim wherein the discharge duct (20) communicates with the inlet of a suction pump (31) downstream of the constriction.

10. A subsea installation incorporating an apparatus as claimed in any preceding claim for mixing or homogenizing crude oil and gas.

11. A subsea installation as claimed in claim 10 wherein the apparatus is incorporated in a cartridge (60) received in a receptacle (61) of the installation into which the cartridge can be placed from surface equipment and from which it can be retrieved.

12. A subsea installation as claimed in claim 11 having sealing means (64,65,66) operative between the cartridge (60) and the receptacle (61), the sealing means defining an entrance chamber and a discharge chamber communicating respectively with an inlet and the discharge duct of the apparatus.

13. A subsea installation as claim d in claim 12 having means for activating the sealing means by hydraulic pressure.

14. A subsea installation as claimed in claim 11, 12 or 13 comprising means (74) for locking the cartridge to the receptacle after reception therein.

15. A subsea installation as claimed in claim 11, 12, 13 or 14 having electrical and/or hydraulic connection means (72,76) between the cartridge and the subsea installation, the connection means being arranged to be effective as a consequence of a stab-in installation of the cartridge in the receptacle.

16. A method of measuring flow of a mixed or homogenized liquid and gas, the method comprising forming a pool (21) of the liquid in a vessel (10) and a body of the gas in the vessel above the liquid pool, discharging the gas from the gas body and the liquid from the liquid pool into a discharge duct (20) constricted to include a venturi, and measuring the flow of the mixed or homogenized liquid and gas through the venturi by sensing pressure change thereat.

17. A method as claimed in claim 16 comprising the step of mixing at least one further liquid or gas from a source external to the vessel with the liquid and the gas at the venturi.

18. A method as claimed in claim 16 or 17 comprising compensating the fluid flow measurement by sensing temperature change at the venturi.

19. A method as claimed in claim 16, 17 or 18 comprising determining mass flow rates of gas and liquid phases in the venturi by density measurement thereat.

20. A method as claimed in any one of claims 16 to 19 comprising co-ordinating the flow of liquid into and out of the pool so as to maintain the level of the liquid pool.

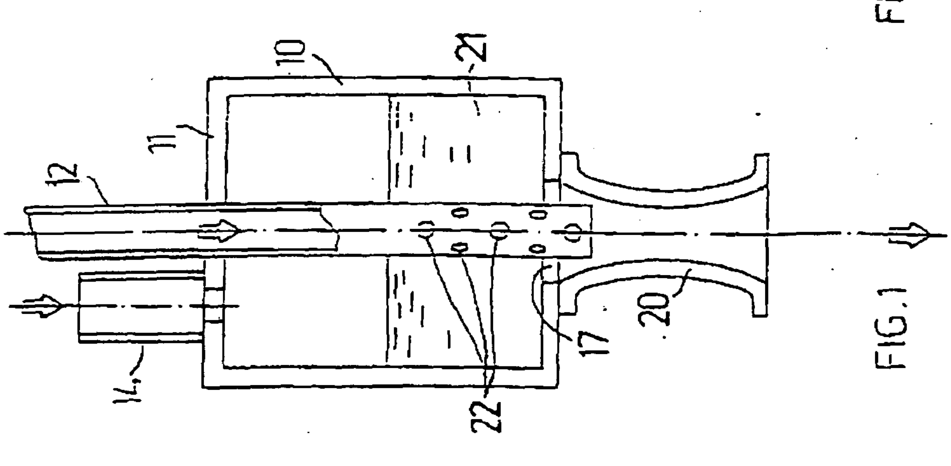

FIG.1

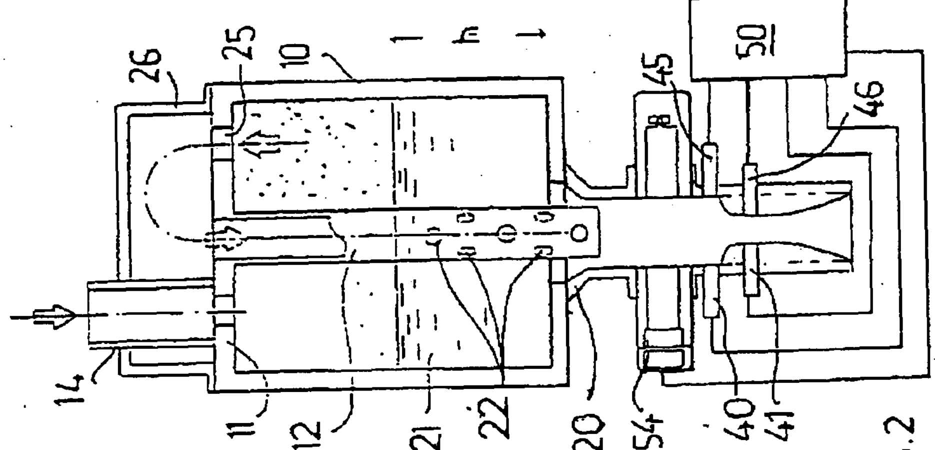

FIG.2

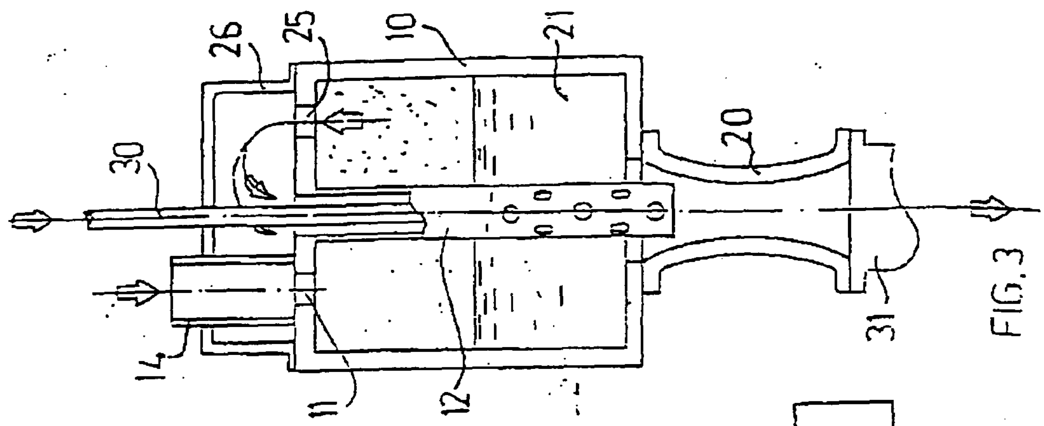

FIG.3

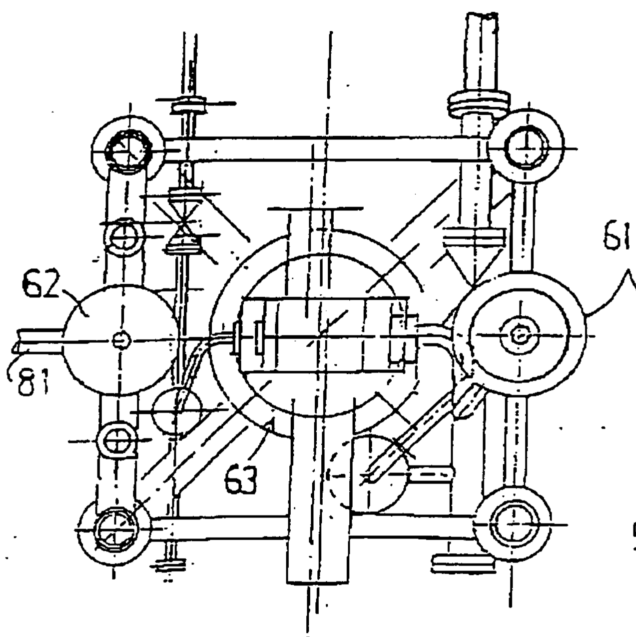

FIG. 6

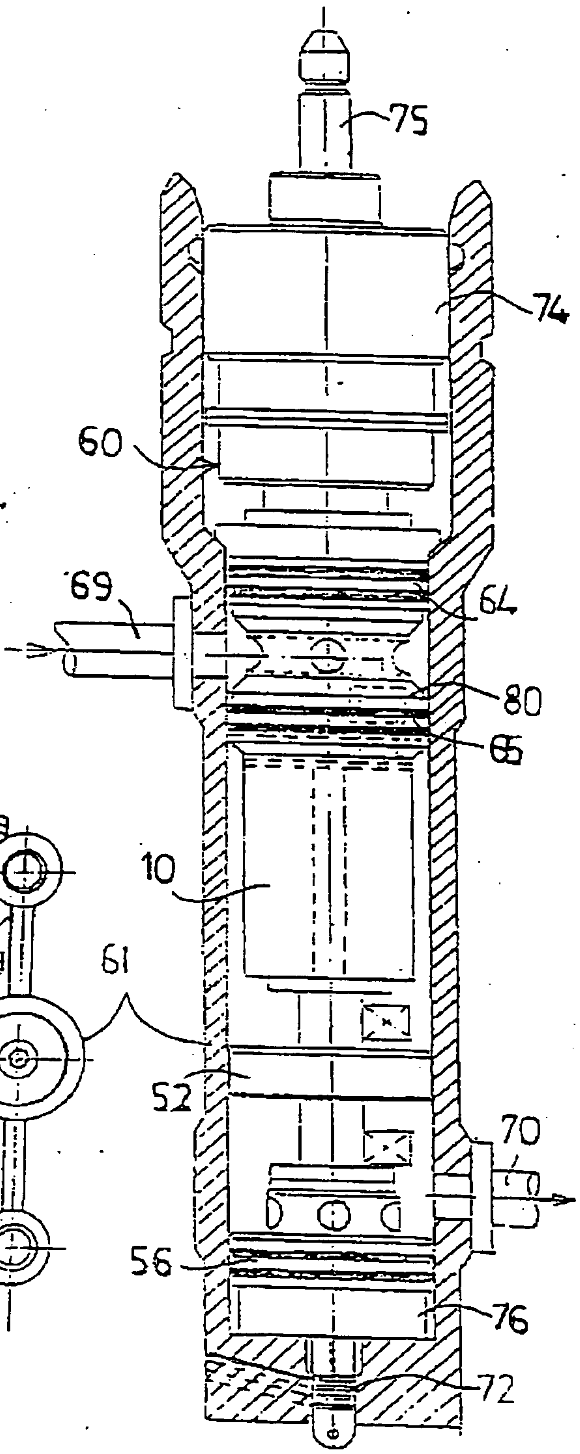

FIG. 4

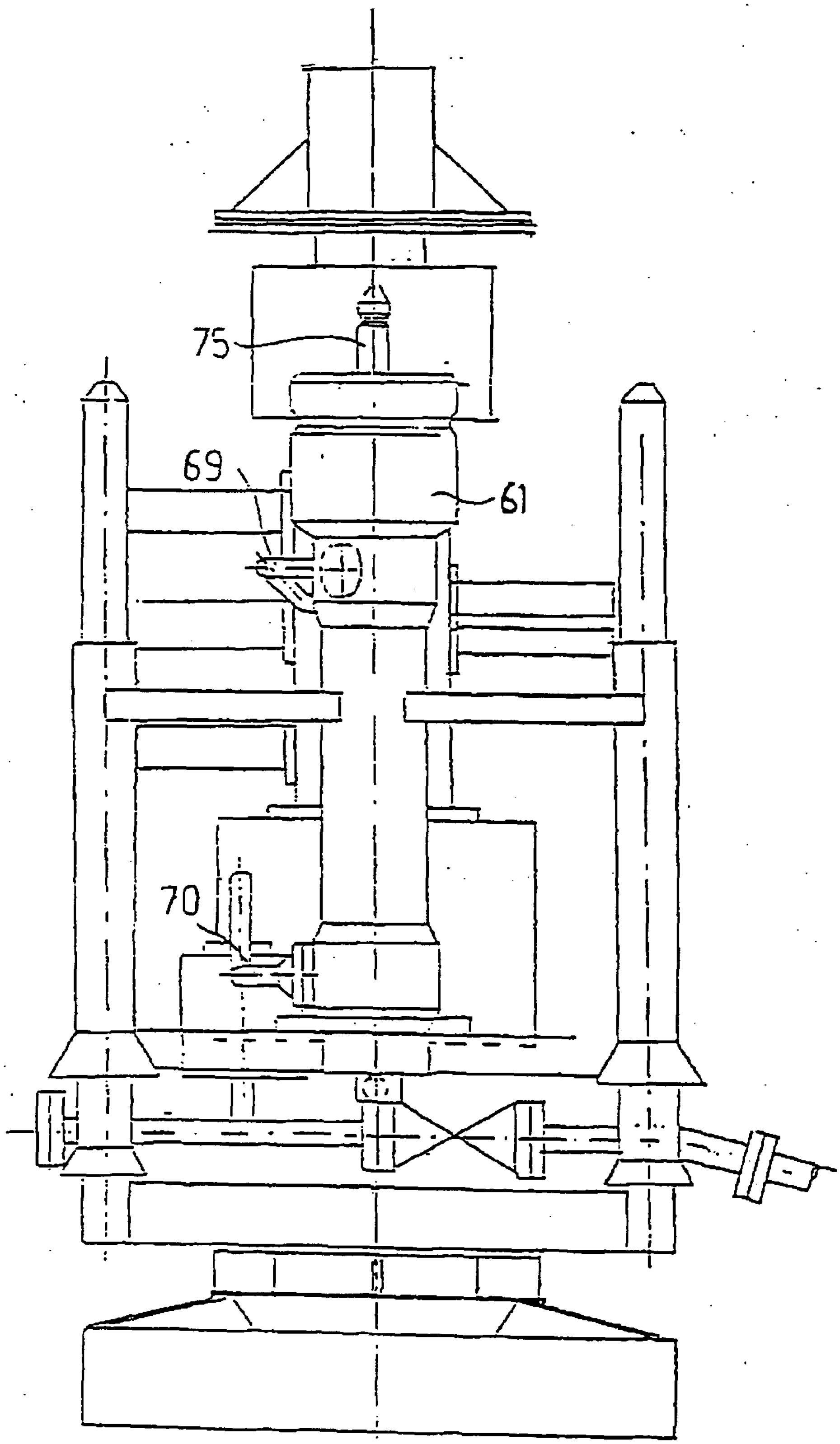

FIG.5

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EUROPEAN SEARCH REPORT

Application Number
EP 95 10 8997

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	GB-A-2 197 675 (BRITISH PETROLEUM COMPANY) * page 6, line 15 - page 11, line 30; figures 1-4 *	1,10-15	G05D11/00
A	US-A-4 604 902 (SABIN ET AL) * column 2, line 33 - column 4, line 68; figure 1 *	1,5,6, 16,18,19	
A	US-A-4 361 187 (LUERS) * column 3, line 43 - column 6, line 20; figures 1-4 *	1,8-10	
A	US-A-4 634 559 (ECKERT) * column 2, line 65 - column 6, line 18; figures 1,2 *	1,2,16	

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

G05D
E21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 July 1995	Calarasanu, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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